$\bar{P}$ PRODUCTION TARGET STUDIES -Numerical Calculations

Thomas B.W.Kirk
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INTRODUCTION

The source for antiprotons for the Tevatron I Project should be as "bright" as possible. Since brightness is connected inversely with emittance and since there is a large angular emittance of the antiprotons due to their production transverse momentum, it is desirable to make the source have the smallest practical spatial size. Two basic considerations limit the spatial dimensions of the source, finite density of real target materials and multiple coulomb scattering in the target itself.

The first effect introduces a "depth of field" optical abberation and the second increases both the angular spread of the source and the effective source size. In practical schemes, the instantaneous and average energy deposition in the target by the proton beam which makes the antiprotons also introduces a "depth of field" optical abberation and the second increases both the angular spread of the source and the effective source size. In practical schemes, the instantaneous and average energy disposition in the target by the proton beam which makes the antiprotons also introduce serious (and to some extend separable) constraints on the problem. Finally, the proton beam incident has a finite emittance of its own which has an impact on the result separable to some extent from the target heating problems. Many people have made estimates and analytic formulations of various combinations of the above factors and drawn conclusions of seemingly contradictory nature. Since a complete numerical calculation of the $\bar{p}$ emittance, including all of the effects in an accurate manner, is possible, it seemed useful to do this calculation and summarize the results for use by optical transport programs concerned with capturing $\bar{p}$'s for cooling and storage.

In this study, the target density will be assumed to remain constant since exploding targets will be very unlikely in a practical scheme. It is further clear that the overall production cross section for $\bar{p}$'s factors out of the problem and is therefore not addressed explicitly here. The production transverse momentum, on the other hand is a crucial factor, and a model for this is introduced. Likewise, chromatic effects due to finite momentum spread of the $\bar{p}$'s is not explicitly carried along, but its effect is presented in one study here.

INPUT MODELS and DATA

Several elements are assumed in making a study of practical use. Let us

a) Proton beam: The incident proton beam is assumed to have a symmetric x and y gaussian emittance in x and x' given by

$$\varepsilon_y = \varepsilon_x \equiv \pi\, \sigma_x \sigma_{x'} = 0.05\, \pi \text{ mm mr. (1 standard deviation)}$$

It is also assumed that the beam size and divergence can be varied within the constraint that phase space(emittance) is conserved.

b) Target: The target is assumed to be tungsten(but if rhenium is used, its parameters are virtually identical) of transverse size large compared to the beam spot. In particular, all particles are assigned multiple scattering(and nuclear attenuation) as though they cannot escape from the sides of the target.

c) $\bar{P}$ Production transverse momentum - the antiprotons are assumed to have a production transverse momentum wrt the proton direction of:

$$\frac{dN}{dP_{\perp}^{2}} = C_0 \; e^{-(P_{\perp x}^2 + P_{\perp y}^2)/2\sigma_{\perp}^2}, \quad \sigma_{\perp} = 0.40 (\text{GeV/c}).$$

d) Target length: Target lengths of 0.0, 2.0, 4.0, 6.0, 8.0 cm are considered.

e) Target efficiency: The yield per incident proton per $\bar{p}$ produced is lowered by attenuation in the target of the incident protons and of the produced $\bar{p}$'s. This efficiency factor F_{tgt} is given by:

$$F_{tgt}(\lambda_p, \lambda_{\bar{p}}, \ell) = \frac{e^{-\ell/\lambda_p} - e^{-\ell/\lambda_{\bar{p}}}}{(\lambda_p/\lambda_{\bar{p}} - 1)},$$

where; ℓ = target length(cm)

λ_p = absorbtion length for high energy(nom 80 GeV) protons(cm)

$\lambda_{\bar{p}}$ = collision length for low energy(nom 5 GeV) antiprotons(cm).

note:

if $\lambda_p = \lambda_{\bar{p}}$, then,

$$F_{tgt}(\lambda, \ell) = \frac{e^{-\ell/\lambda}}{\lambda/\ell}.$$

We choose $\lambda_p \cong 10$ cm, $5 < \lambda_{\bar{p}} < 10$ cm .

f) Multiple scattering: The projected multiple scattering in a "thick" target is a correlated two dimensional gaussian in position and slope, and is given by:

$$\frac{d^2P(\rho,\, x',\, t)}{dxdx'} = C_0 e^{-B(x'^2 - 3x'\rho + 3\rho^2)}$$

where;

x' = change in slope(angle) due to multiple scattering in a distance t

$\rho \equiv (x/t)$ = change in transverse position x from the unscattered orbit by traversing a thickness t of multiple scattering material

$B \equiv 4\left(\frac{\beta P}{E_s}\right)\left(\frac{x_0}{t}\right)$

E_s = .021 (GeV)

P, E = particle momentum(GeV/c), total energy(GeV)

$\beta \equiv P/E$ = Lorentz velocity parameter

x_o = radiation length of scatterer(cm)

x_0 = 0.35 cm (tungsten), 155.0cm(lithium)

t = thickness of scatterer (cm)

$C_0 = \frac{2\sqrt{3}}{\pi} \frac{x_0(\beta P)^2}{t^2(E_s^2)}$ = normalization constant.

When applying multiple scattering to an optical system, the position/angle correlation must be explicitly acknowledged or erroneous results may be obtained. The spatial multiple scattering distribution accurately factors into the product of the projected multiple scattering in the two perpendicular directions for small angle trajectories(the case at hand).

g) Lithium lens: The antiproton beam emerges from the production target at 5.35 GeV/c momentum and with relatively large transverse momentum in the current Tevatron I plan. To capture a large fraction of these $\bar{p}$'s, a monopole lens made from lithium carrying a large pulsed current is proposed. The multiple scattering and nuclear attenuation in the lens is of interest, so its effects have been included. We describe the lens by:

L = length = 10.0 cm

G = magnetic gradient = 100.0 KG/cm

With these elements, we can monte-carlo the emittance of the $\bar{p}$'s. The method is to choose 10,000 rays from a gaussian proton beam phase space in x and x', assume a $\bar{p}$ produced uniformly along a target of length T with a projected transverse momentum chosen according to an gaussian distribution in $P_\perp$ as in c), and propagate this ray with multiple scattering through the remaining target, across a 20.0 cm drift space(measured from the center of the production target) and on through the lithium lens(also with multiple scattering). From this point, the ray can be propagated forward to the focus of the lithium lens or backward (without scattering) to the center of the production target. In both these locations, the thin target phase ellipse in(x,x') is erect and the one dimensional distributions for a thin target slice are simple.

The actual distributions are not simple for targets of length several centimeters due to depth of field distortions. That, of course, is the whole reason for doing the problem numerically!

RESULTS

The most direct way to present the results of the monte-carlo calculation is in the form of a density plot of numbers of $\bar{p}$'s in small bins of x and x', the transverse position and slope of $\bar{p}$ rays from the production target. As noted above, all rays are presented as they reproject to the center of the production target. In some cases, the detailed distribution at the "hot spot" near x = 0.0, x' = 0.0 is presented in a second plot with finer bin size.

In each of the plots in Figures 2-19, the numbers shown in each bin in the (x, x') plot represent those particles out of a sample of 10,000 produced $\bar{p}$'s that ended up in a particular piece of phase space. Note that this is a two dimensional study in one transverse coordinate, hence the yields into a three dimensional solid angle go as this projected result squared only for small solid angles. Since real beam transports will find it hard to subtend large parts of the phase space, the projected results are nevertheless useful.

The plots labeled "Correlation Plot No.3" have bins of 0.04 cm in x and 10.0 milliradians in x'. The border around the central 400 bins gives the overflow events that do not fit into the scale of the plot. The bottom row and rightmost column give the sums of their respective columns and rows, respectively. The plots labeled "Correlation Plot 4" give the same results in a magnified central region with x bins of 0.02 cm and x' bins of 4.0 mr. The parameters of beam, target and Li lens are included on the plot. Multiple scattering in the target and lens are included unless noted otherwise.

Figure 1 shows the geometry of the problem and Table I summarizes the cases plotted in Figures 2-17.

TABLE I

Correlation Plots for $\bar{p}$ Production in Tungsten Targets

Figure Number	Beam RMS Width (mm)	Beam RMS Slope (mr)	Target Length(cm)	Target Multiple Scattering	Li Lens Multiple Scattering	Comments
2	0.300	0.167	0.0	YES	YES	Target length study with all multiple scattering and "large" incident proton beam
3	"	"	0.0	"	"	
4	"	"	2.0	"	"	
5	"	"	4.0	"	"	
6	"	"	4.0	"	"	
7	"	"	6.0	"	"	
8	"	"	8.0	"	"	
9	"	"	8.0	"	"	
10	0.075	0.067	4.0	"	"	"Small" beam study with full multiple scattering
11	"	"	4.0	"	"	
12	0.0	0.0	0.0	NO	NO	Phase space for point $\bar{p}$ source
13	"	"	0.0	"	"	
14	"	"	4.0	"	"	Finite target length effect
15	"	"	4.0	"	"	
16	"	"	0.0	"	YES	Effect of multiple scattering in LiLens
17	"	"	0.0	"	YES	
18	0.300	0.167	4.0	YES	YES	$\Delta P/P = \pm 2\%$ added to show chromatic behavior
19	"	"	4.0	"	"	

INTERPRETATION

The raw phase space density data contained in the plots of Table I can be presented in a number of useful ways. Before combining the effects of beam attenuation in the(finite) target with attenuation of the produced $\bar{p}$'s in the same target, it is useful to study the effects of proton beam radius and target length normalized to the same number of $\bar{p}$'s emerging from the target. Later, the various attenuation and production factors can be multiplied by the densities to get the actual production members. In all cases we study, the full multiple scattering of the target and lithium lens is included.

In Figure 20, the phase space density of the "hot spot" at x = 0.0, x' = 0.0 is plotted versus target length for several incident proton beam radii. The central brightness varies weakly with target length over the range 0-8.0 cm. Likewise, there is a gentle dependence on proton beam radius for radii in the range 0-0.30 mm.

This latter result is seen more clearly in Figure 21 where the central density is plotted versus rms beam radius for several target lengths. Note that the beam phase space density is held constant for each beam radius as is necessary for any real beam focussing system. The phase space density of the incident proton beam is assumed to be 0.05 π mm mr as noted above. The central phase space density is a concept of limited usefulness. It is primarily valuable for small $\bar{p}$ phase space acceptances, in which circumstances the yield into an acceptance $\varepsilon_x\varepsilon_y$ is given by:

$$Y \cong \left.\frac{d^2N}{dxdx'}\right|_0 \varepsilon_x\varepsilon_y$$

$$\equiv \int_{-y}^{+y}\int_{-y'}^{+y'}\int_{-x}^{+x}\int_{-x'}^{+x'} dxdx'dydy' \frac{d^4N}{dxdx'dydy'} .$$

For finite solid angle acceptance of $\bar{p}$'s, the numerical integral over discrete regions of phase space is more useful. In the case of Figures 2-19, this integral is proportional to the sum over the desired ranges of x and x'. In the limit where multiple Coulomb scattering and $\bar{p}$ transverse momentum are both gaussian in the transverse spatial directions(a good approximation for all cases of practical interest), the full four dimensional phase acceptance goes as the product of the(x,x') and (y, y') projections. This being the case, each count in a correlation plot bin represents 1.0×10^{-4} of the $\bar{p}$'s produced in the target.

Figure 22 shows the fractional yields as a function of ε_x for symmetric (x, x'), (y,y') values of the $\bar{p}$ emittance. The curves are parametric in target length and assume a proton beam of 0.30 mm x 0.167 mr. Full multiple scattering is included; the beam and $\bar{p}$ attenuation factors are not included at this point. The curves verify the unremarkable fact that large acceptance means efficient collection while small acceptance means small yield. This is not news, but it is useful to see the dramatic increase in $\bar{p}$ collection as ε_x varies from 5π to say 50π mm mr.

Note carefully that the emittance integral is over rectangular regions in (x, x') phase space rather than the conventional elliptical ones. When comparing these emittances to an acceptance that is elliptical in (x, x'), but which is nevertheless limited by discrete angular limits, a factor of $(\pi/4)$ may be needed to obtain the elliptical admittance from the rectangular emittance for fixed angular boundaries.

The effect of finite target length on beam and $\bar{p}$ attenuation is shown in Figure 23. The best model for proton beam and $\bar{p}$ attenuation probably lies between the two extreme cases shown. If elastic scattering of protons is ignored(a good assumption) then λ = 10 cm. If elastic scattering of $\bar{p}$'s is ignored(a questionable, but not unreasonable assumption), then $\lambda_{\bar{p}}$ = 10 cm. If elastically scattered p's are assumed lost, $\lambda_{\bar{p}}$ = 5 cm. Real life probably lies nearer the $\lambda_{\bar{p}}$ = 10 cm limit.

In Figure 24, the target attenuation factor from Figure 23 multiplies the fractional yields of Figure 22 to produce the actual target length dependent yields in tungsten. To obtain the absolute yield of $\bar{p}$'s, it is only necessary to multiply the ordinate shown by the fraction of inelastic proton collisions that produce one or more antiprotons in the accepted $\bar{p}$ momentum interval. If the momentum acceptance exceeds a few precent, integration of the production over the momentum interval may be necessary.

The $\bar{p}$ yield is finally the important quantity of interest. It can be given by the equation:

$$N_{\bar{p}} = N_p t f_{TGT} \Delta\sigma \equiv 2\pi N_p \left(\frac{Ed^3\sigma}{dP^3}\right)_o \sigma_\perp^2 \ \frac{\Delta P_\parallel}{E} \ A(t,\varepsilon)$$

where; $N_{\bar{p}}$ = no. of $\bar{p}$'s produced from target t with mean total energy E, in the momentum interval $\Delta P_\parallel$, captured in the symmetric emittance

$\varepsilon_x = \varepsilon_y \equiv \varepsilon$

N_p = no. of beam protons incident on the target

$t = N_o \rho \ell$

$N_o = 6.02 \times 10^{23}$ (Avagadro's Number)

ρ = density of tungsten (gm/cm^3)

ℓ = target length (cm)

f_{TGT} = finite target length factor (see Figure 23)

$$\Delta\sigma = \int_0^{P_\perp^2 \max} \int_{P_\parallel \min}^{P_\parallel \max} \frac{d^2\sigma}{dP_\perp^2 dP_\parallel} \, dP_\perp^2 dP_\parallel \qquad (\text{cm}^2)$$

$E = \bar{p}$ total energy (GeV)

$\Delta P_\parallel$ = accepted $\bar{p}$ momentum bite(GeV/c)

$\sigma_\perp^2$ = variance for the assumed $\bar{p}$ production transverse momentum (assumed gaussian), (GeV/c)^2

$\left(\frac{Ed^3\sigma}{dP^3}\right)_o$ = invariant <u>per nucleon</u> $\bar{p}$ production cross section evaluated at $P_\perp = 0$, E (cm^2/GeV^2)

$A(t,\varepsilon)$ = all the geometrical and target length effects. This is the factor that must be computed numerically. Its value varies from 0 to 1.0; it is dimensionless.

Several of the numbers needed for numerically calculating the $\bar{p}$ yields are uncertain. The values for $\sigma_\perp^2$ and $\left(\frac{Ed^3\sigma}{dP^3}\right)_o$ are known only approximately.

Nevertheless, by assuming specific values, we can demonstrate $\bar{p}$ yields explicitly. The values we choose are given by:

$N_p = 10^{13}$

$\sigma_\perp^2 = 0.16$ (GeV/c)^2

$$\left(\frac{Ed^3\sigma}{dP^3}\right)_o = 1.0 \ \frac{\text{mb}}{\text{GeV}^2} = \frac{1.0 \times 10^{-27}\text{cm}^2}{\text{GeV}^2} \ @ \ E = 5.4 \text{ GeV}$$

$\Delta P_\parallel / E = 0.04$

With these values, the actual $\bar{p}$ yields are shown on the right hand scale in Figure 24. From the graph, the emittance and target length dependences are quite clear.

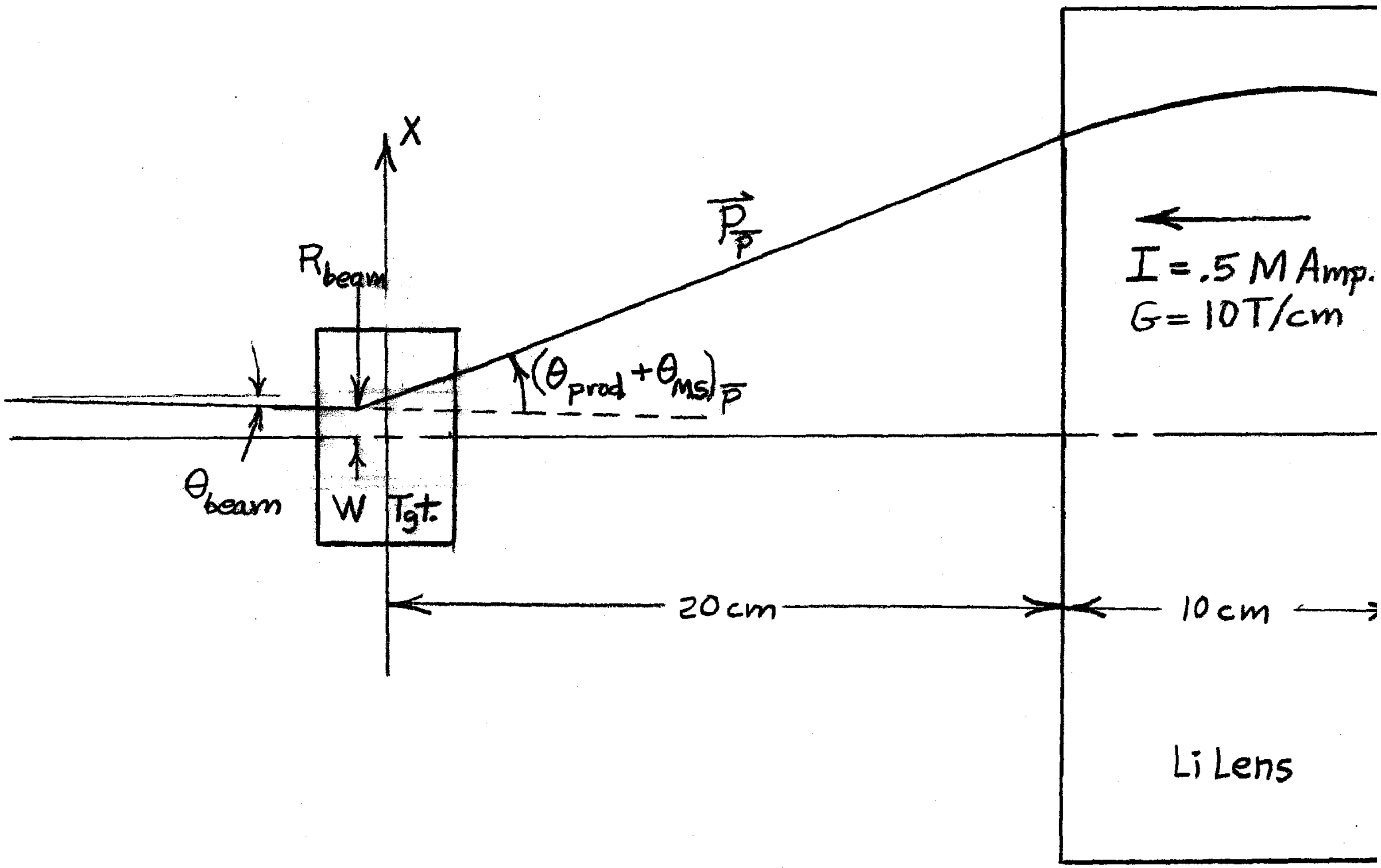

Fig 1
$\bar{P}$ Target Geometry

CORRELATION PLOT NO 3
HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)
VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.4000

0	0	0	0	0	0	0	0	5	45	118	110	29	3	0	0	0	0	0	0	0

100.0000

0	0	0	0	0	0	0	0	1	21	45	65	18	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	4	25	72	69	31	7	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	2	31	82	95	29	4	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	7	41	149	134	44	3	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	2	55	178	150	40	6	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	9	69	198	184	61	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	3	76	240	230	64	5	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	7	82	258	260	75	7	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	8	98	289	265	86	6	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	9	81	277	241	78	5	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	10	94	276	248	77	10	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	8	88	253	270	77	11	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	5	96	283	252	79	8	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	7	68	214	238	69	7	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	7	59	183	193	63	5	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	6	52	153	172	64	9	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	4	40	140	130	45	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	3	27	105	98	28	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	24	84	84	29	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	24	102	93	30	5	1	0	0	0	0	0	0

-100.0000

0	0	0	0	0	0	0	0	1	20	77	65	19	0	0	0	0	0	0	0	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	0	0	0	0	1	104	1151	3579	3481	1087	104	1	0	0	0	0	0	0

PROTON BEAM RADIUS	=	.0300 CM
PROTON BEAM SLOPE	=	.1657 MILLI RADIANS
TARGET LENGTH	=	0.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3555 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Full Mult. Scatt.

Fig 2

CORRELATION PLOT NO 4

HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.2000

0	0	0	0	0	9	21	76	211	370	473	462	345	175	76	21	5	0	0	0	0

40.0000

0	0	0	0	0	1	1	9	23	41	46	49	34	22	7	2	0	0	0	0	0
0	0	0	0	0	0	1	11	14	40	59	62	33	15	9	2	1	0	0	0	0
0	0	0	0	0	0	1	14	24	33	61	70	34	18	8	2	0	0	0	0	0
0	0	0	0	0	2	0	8	25	51	62	56	42	18	7	1	1	0	0	0	0
0	0	0	0	0	1	3	5	25	51	55	71	39	17	17	1	2	0	0	0	0
0	0	0	0	0	0	1	7	31	54	72	53	41	27	7	0	1	0	0	0	0
0	0	0	0	0	1	5	12	25	42	68	66	55	27	10	3	2	0	0	0	0
0	0	0	0	0	0	3	8	30	45	60	62	33	15	9	1	0	0	0	0	0
0	0	0	0	1	1	4	8	27	43	65	60	41	15	13	2	0	0	0	0	0
0	0	0	0	0	0	2	10	21	54	63	59	36	30	11	2	0	0	0	0	0
0	0	0	0	0	0	3	7	22	42	69	55	42	25	14	3	1	0	0	0	0
0	0	0	0	0	0	4	14	26	48	65	64	32	14	10	3	0	0	0	0	0
0	0	0	0	0	1	2	14	32	34	69	63	47	20	14	5	0	0	0	0	0
0	0	0	0	0	1	5	9	19	37	61	56	42	23	8	3	1	0	0	0	0
0	0	0	0	0	0	2	14	25	33	67	67	50	21	5	4	1	0	0	0	0
0	0	0	0	0	2	1	10	31	50	59	56	39	27	7	2	0	0	0	0	0
0	0	0	0	0	0	2	11	26	57	77	65	43	25	5	3	2	0	0	0	0
0	0	0	0	0	0	2	14	21	27	49	53	58	20	8	2	0	0	0	0	0
0	0	0	0	0	0	1	7	21	36	55	39	40	24	11	1	2	0	0	0	0
0	0	0	0	0	0	6	9	41	69	94	105	65	33	12	3	2	0	0	0	0

-40.0000

0	0	0	0	0	1	20	57	162	300	468	448	313	187	67	20	0	1	0	0	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	0	1	10	49	201	509	887	1276	1241	847	437	192	45	16	0	0	0	0

PROTON BEAM RADIUS	=	.0300 CM
PROTON BEAM SLOPE	=	.1557 MILLI RADIANS
TARGET LENGTH	=	0.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3565 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Full Mult. Scatt.

Fig 3

CORRELATION PLOT NO 3

HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.4000																				
0	0	0	0	0	1	5	15	21	42	60	49	48	38	15	4	0	0	0	0	0
100.0000																				
0	0	0	0	0	0	1	2	18	24	32	31	44	12	5	1	0	0	0	0	0
0	0	0	0	0	0	0	3	13	41	40	55	48	22	4	0	0	0	0	0	0
0	0	0	0	0	0	0	2	17	55	69	67	57	24	2	0	0	0	0	0	0
0	0	0	0	0	0	0	4	22	60	116	99	55	21	2	0	0	0	0	0	0
0	0	0	0	0	0	0	2	19	79	117	141	70	25	1	0	0	0	0	0	0
0	0	0	0	0	0	0	1	19	76	169	158	80	15	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	12	92	230	200	79	21	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	15	80	264	231	58	13	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	6	90	278	229	83	7	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	4	83	279	254	73	9	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	6	74	262	291	88	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	18	83	258	265	100	5	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	14	79	210	209	93	13	0	0	0	0	0	0	0
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0	0	0	0	0	0	0	4	26	54	77	64	43	19	4	0	0	0	0	0	0
0	0	0	0	0	0	0	3	16	44	49	48	45	23	2	0	0	0	0	0	0
0	0	0	0	0	0	0	9	34	38	42	55	39	22	7	1	0	0	0	0	0
-100.0000																				
0	0	0	0	0	0	2	7	21	34	33	24	33	30	14	3	0	0	0	0	0
SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN																				
0	0	0	0	0	0	1	37	334	1355	3084	2986	1355	315	32	2	0	0	0	0	0

PROTON BEAM RADIUS = .0300 CM
PROTON BEAM SLOPE = .1657 MILLI RADIANS
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P BAR RMS P PERP = .4000 GEV/C
LI LENS GRADIENT = 100.0000 KG/CM
LI LENS LENGTH = 10.0000 CM

Full Mult. Scatt.

Fig 4

CORRELATION PLOT NO 3
HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)
VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.4000 .4000

0	0	0	0	10	14	14	21	26	19	45	30	25	28	31	22	13	10	4	0	0	0	0
100.0000																						
0	0	0	0	1	1	18	12	19	21	14	10	21	28	18	6	4	0	0	0	0	0	173
0	0	0	0	0	2	9	23	21	21	28	26	29	25	15	5	2	0	0	0	0	0	206
0	0	0	0	0	1	6	23	32	35	38	48	38	36	24	5	4	0	0	0	0	0	290
0	0	0	0	0	0	10	28	51	65	57	55	57	55	15	8	1	0	0	0	0	0	402
0	0	0	0	0	0	2	20	52	85	70	71	78	39	15	1	0	0	0	0	0	0	433
0	0	0	0	0	0	1	13	45	105	109	109	82	55	11	1	0	0	0	0	0	0	531
0	0	0	0	0	0	0	4	44	115	161	155	98	35	8	0	0	0	0	0	0	0	620
0	0	0	0	0	0	1	1	28	99	214	198	87	31	4	1	0	0	0	0	0	0	654
0	0	0	0	0	0	0	0	15	89	252	206	104	19	0	0	0	0	0	0	0	0	695
0	0	0	0	0	0	0	0	8	90	263	266	103	10	1	0	0	0	0	0	0	0	741
0	0	0	0	0	0	0	1	8	84	256	281	90	5	0	0	0	0	0	0	0	0	726
0	0	0	0	0	0	0	1	23	99	250	244	94	12	0	0	0	0	0	0	0	0	723
0	0	0	0	0	0	1	4	28	85	181	211	110	24	1	0	0	0	0	0	0	0	645
0	0	0	0	0	0	0	15	31	96	157	153	126	27	3	0	0	0	0	0	0	0	608
0	0	0	0	0	0	2	11	51	86	112	125	85	49	7	1	0	0	0	0	0	0	529
0	0	0	0	0	0	2	22	44	71	87	69	74	56	25	5	0	0	0	0	0	0	455
0	0	0	0	0	0	9	23	44	60	57	55	47	35	18	6	0	0	0	0	0	0	354
0	0	0	0	0	2	9	19	32	28	33	39	32	32	28	8	0	0	0	0	0	0	262
0	0	0	0	1	3	12	11	22	24	23	33	26	24	17	12	1	0	0	0	0	0	209
0	0	0	0	2	7	17	26	29	29	23	24	27	29	34	19	7	1	0	0	0	0	274
-100.0000																						
0	0	1	2	3	10	10	13	13	15	10	12	12	13	12	14	8	8	0	0	0	0	0
SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN																						
0	0	0	0	4	16	99	257	627	1387	2385	2378	1408	627	244	78	19	1	0	0	0	0	9530

PROTON BEAM RADIUS = .0300 CM
PROTON BEAM SLOPE = .1657 MILLI RADIANS
TARGET LENGTH = 4.0000 CM TUNGSTEN
P BAR KINETIC ENERGY = 4.5000 GEV
P BAR MOMENTUM = 5.3565 GEV/C
P BAR RMS P PERP = .4000 GEV/C
LI LENS GRADIENT = 100.0000 KG/CM
LI LENS LENGTH = 10.0000 CM

Full Mult. Scatt.

Fig 5

CORRELATION PLOT NO 6

HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.2000 .2000

22	30	37	55	84	105	141	159	192	173	188	181	168	192	148	134	132	66	63	27	21	38	0

40.0000

0	0	0	1	2	6	21	16	23	25	28	37	27	18	20	9	9	1	1	0	0	0	244
0	0	0	0	1	2	11	17	30	33	38	39	30	33	9	10	3	5	0	0	0	0	258
0	0	1	0	1	3	6	20	29	36	45	40	21	28	17	9	2	0	2	0	0	0	260
0	0	0	0	0	4	11	13	26	41	45	56	33	17	17	8	4	3	0	1	0	0	279
0	0	0	0	0	0	8	12	28	41	43	43	27	17	12	9	3	0	0	0	0	0	243
0	0	0	0	0	1	3	12	31	45	59	45	32	22	13	3	0	0	0	0	0	0	266
0	0	0	0	0	0	5	11	18	50	46	63	34	33	17	6	4	0	0	0	0	0	281
0	0	0	0	0	1	8	19	27	49	49	53	38	24	22	6	3	0	1	0	0	0	300
0	0	0	0	0	0	2	8	30	44	55	58	43	34	7	0	0	0	0	0	0	0	281
0	0	0	0	0	1	2	7	16	56	62	66	43	25	13	6	1	0	0	0	0	0	298
0	0	0	0	0	1	2	4	21	41	54	60	51	27	16	2	0	0	0	0	0	0	279
0	0	0	0	1	0	4	14	28	43	61	68	53	33	5	4	0	0	0	0	0	0	314
0	0	0	0	0	1	7	17	21	51	70	56	52	18	15	3	0	0	0	0	0	0	311
0	0	0	0	0	0	5	18	22	51	56	59	36	27	9	3	1	0	0	0	0	0	287
0	0	0	0	1	4	7	12	26	35	44	47	43	26	8	4	1	0	0	0	0	0	258
0	0	0	0	1	4	9	12	25	21	46	48	34	24	19	8	3	0	0	0	0	0	254
0	0	1	0	2	2	6	9	22	36	42	49	36	28	19	7	0	1	0	0	0	0	260
0	0	0	0	7	3	14	8	30	31	43	44	38	31	18	5	4	0	0	0	0	0	276
0	0	0	0	1	3	6	20	19	34	35	30	36	30	24	10	1	3	0	0	0	0	252
0	0	1	2	10	8	24	34	41	51	49	57	50	47	37	25	12	1	1	0	0	0	450

-40.0000

18	36	37	51	70	74	141	125	149	142	153	140	159	129	133	116	100	79	60	41	24	25	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	3	3	27	44	161	283	513	814	970	1015	757	535	317	137	51	14	5	1	0	0	5651

PROTON BEAM RADIUS	=	.0300 CM
PROTON BEAM SLOPE	=	.1657 MILLI RADIANS
TARGET LENGTH	=	4.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3555 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Full. Mult. Scatt.

Fig 6

CORRELATION PLOT NO 3

HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.4000 .4000

2	5	10	10	17	10	17	22	19	19	17	21	26	22	22	20	18	16	22	7	5	2	0

100.0000

0	1	0	3	9	11	13	10	11	5	10	9	13	14	14	8	10	9	4	1	0	1	155
0	0	1	1	7	14	22	22	18	19	19	26	16	17	14	18	11	4	3	0	0	0	232
0	0	0	1	8	14	26	31	27	27	25	22	26	19	17	16	13	4	1	0	0	0	276
0	0	0	0	3	10	25	34	42	52	40	45	25	42	24	13	10	0	1	0	0	0	366
0	0	0	0	0	5	18	34	61	49	56	42	68	45	40	17	3	3	0	0	0	0	442
0	0	0	0	0	1	10	34	78	73	85	74	73	55	36	16	4	0	0	0	0	0	540
0	0	0	0	0	0	2	13	59	122	119	129	89	55	15	9	0	1	0	0	0	0	613
0	0	0	0	0	0	1	8	37	124	173	167	93	33	18	0	1	0	0	0	0	0	651
0	0	0	0	0	0	0	0	30	116	205	168	102	34	7	0	0	0	0	0	0	0	662
0	0	0	0	0	0	0	2	20	99	244	216	105	21	3	0	0	0	0	0	0	0	711
0	0	0	0	0	0	0	4	7	101	256	235	109	11	1	0	0	0	0	0	0	0	724
0	0	0	0	0	0	0	12	38	95	186	202	120	37	4	0	0	0	0	0	0	0	684
0	0	0	0	0	1	7	21	44	98	145	185	120	55	5	0	0	0	0	0	0	0	693
0	0	0	0	0	3	8	18	58	90	123	144	124	62	28	1	0	0	0	0	0	0	659
0	0	0	0	0	1	9	34	53	69	86	92	75	57	35	7	1	0	0	0	0	0	519
0	0	0	0	2	5	17	39	52	47	48	61	57	49	33	33	7	0	0	0	0	0	449
0	0	0	1	2	5	10	27	33	33	33	47	55	37	29	16	15	1	0	0	0	0	345
0	0	1	2	4	7	13	18	23	27	20	21	32	23	26	27	10	5	0	0	0	0	259
0	0	0	4	9	7	10	16	20	25	12	21	22	9	17	23	16	5	2	0	0	0	218
0	0	3	4	16	13	15	23	16	18	21	20	19	18	15	25	19	10	8	3	0	0	266

-100.0000

2	7	10	8	15	7	12	9	10	14	10	13	17	11	12	7	12	7	11	5	4	3	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	1	5	16	60	98	206	400	727	1279	1908	1926	1344	599	381	229	120	42	19	4	0	0	9464

PROTON BEAM RADIUS	=	.0300	CM
PROTON BEAM SLOPE	=	.1657	MILLI RADIANS
TARGET LENGTH	=	6.0000	CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000	GEV
P BAR MOMENTUM	=	5.3565	GEV/C
P BAR RMS P PERP	=	.4000	GEV/C
LI LENS GRADIENT	=	100.0000	KG/CM
LI LENS LENGTH	=	10.0000	CM

Full Mult. Scatt.

Fig 7

CORRELATION PLOT NO 3

HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.4000 .4000

11	25	15	5	13	13	10	7	12	14	13	6	24	20	16	9	12	16	15	9	12	25	0

100.0000

0	5	6	12	6	7	12	6	8	2	14	7	5	11	12	9	11	8	10	5	1	3	157
0	1	7	15	14	14	11	7	11	17	14	14	15	15	23	13	16	8	4	2	4	1	226
0	1	2	12	11	27	16	24	21	16	19	20	14	27	16	13	15	7	5	3	0	1	269
0	0	0	2	15	22	41	19	24	33	30	37	26	29	32	21	32	16	5	3	1	0	383
0	0	0	1	5	18	23	40	38	40	56	41	52	42	31	29	14	8	3	0	0	2	441
0	0	0	1	1	7	32	53	51	63	58	54	69	44	27	15	12	3	2	0	0	0	492
0	0	0	0	0	1	14	35	96	91	105	81	91	55	31	20	7	2	0	0	0	0	629
0	0	0	0	0	0	1	24	83	120	145	115	69	45	17	11	3	1	1	0	0	0	636
0	0	0	0	0	0	0	4	34	123	198	164	106	39	18	2	2	0	0	0	0	0	690
0	0	0	0	0	0	1	5	31	115	234	241	104	38	8	1	0	0	0	0	0	0	778
0	0	0	0	0	0	2	4	31	90	170	241	130	19	4	3	0	0	0	0	0	0	694
0	0	0	0	0	0	6	14	42	107	143	212	137	45	3	0	0	0	0	0	0	0	709
0	0	0	0	1	2	12	22	53	82	110	129	117	74	21	3	0	0	0	0	0	0	626
0	0	0	2	2	5	15	29	60	73	92	84	108	89	39	12	2	0	0	0	0	0	615
0	0	0	1	4	17	22	39	59	61	65	61	62	65	52	32	6	0	0	0	0	0	546
0	1	1	2	4	13	36	28	35	47	39	33	37	44	36	30	25	2	2	0	0	0	416
0	2	2	9	14	15	27	22	29	28	31	39	23	35	31	22	23	14	4	0	0	0	370
0	2	4	7	16	21	15	17	24	27	22	15	29	17	19	19	25	12	10	4	0	0	306
3	4	6	12	13	14	25	13	8	8	23	16	10	9	13	14	17	16	8	3	1	0	233
1	8	10	14	10	15	19	11	15	14	14	10	20	12	21	14	11	13	13	9	13	5	266

-100.0000

12	16	6	5	8	5	11	11	8	9	16	7	6	11	7	12	9	8	3	13	6	10	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	24	39	90	116	198	333	416	753	1157	1582	1610	1224	755	454	283	223	110	67	29	20	0	9482

PROTON BEAM RADIUS	=	.0300 CM
PROTON BEAM SLOPE	=	.1657 MILLI RADIANS
TARGET LENGTH	=	8.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3555 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Full Mult. Scatt.

Fig 8

CORRELATION PLOT NO 4

HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.2000

247	118	75	83	73	77	88	87	98	106	98	83	91	109	97	95	93	92	65	57	52

40.0000

0	2	3	10	11	15	23	10	10	11	15	9	14	12	21	15	7	7	3	2	6
0	3	5	3	6	22	17	24	28	27	19	25	18	13	17	11	11	10	6	4	4
0	1	0	1	10	21	19	21	21	22	34	18	11	18	14	12	7	5	4	3	4
0	0	0	5	6	9	26	25	21	29	40	23	23	15	10	11	5	5	1	3	3
0	0	1	0	7	7	19	21	30	27	25	30	26	15	16	16	6	4	3	1	1
0	0	0	0	2	4	13	25	19	38	41	34	27	29	14	10	7	6	4	0	0
0	0	0	0	1	7	7	25	30	39	47	31	32	24	14	7	6	4	1	0	0
0	0	0	0	1	2	4	21	35	36	44	56	39	26	15	14	7	6	3	2	0
0	1	0	1	2	5	11	12	27	45	45	54	28	39	15	11	7	0	1	1	0
0	0	0	1	1	2	10	17	27	43	53	57	47	21	13	5	3	1	0	0	0
0	0	0	0	1	3	3	14	27	39	39	67	39	30	22	4	2	0	1	0	0
0	0	1	1	0	6	10	10	20	30	34	54	42	32	18	7	1	1	0	2	0
0	0	2	1	3	8	4	16	27	20	36	44	39	35	28	7	2	2	0	0	1
0	1	0	3	1	9	14	17	26	29	34	33	39	34	17	10	4	1	0	0	0
0	0	4	2	6	5	11	17	23	21	31	45	51	25	24	17	10	1	1	0	0
0	3	3	4	7	13	17	15	14	18	29	26	26	25	21	8	11	5	0	0	0
1	2	4	1	3	4	12	13	21	25	20	21	29	27	22	20	12	7	3	2	1
4	3	3	9	4	9	12	10	22	20	25	22	25	19	21	22	20	7	3	0	0
2	3	4	11	6	11	9	16	15	13	16	16	19	22	22	25	11	11	7	1	4
4	7	13	10	11	22	18	31	32	28	38	28	25	35	32	36	23	19	22	13	5

-40.0000

244	127	57	61	66	86	78	76	83	98	83	85	73	82	83	77	91	84	71	69	63

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	26	44	62	89	185	259	361	475	561	665	693	598	507	376	268	162	102	63	34	29

PROTON BEAM RADIUS	=	.0300 CM
PROTON BEAM SLOPE	=	.1667 MILLI RADIANS
TARGET LENGTH	=	8.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3555 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Full Mult. Scatt.

Fig 9

CORRELATION PLOT NO 3
HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)
VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.4000 .4000

0	0	0	0	5	13	20	21	26	20	40	28	35	23	33	17	24	4	1	1	0	0	0
100.0000																						
0	0	0	0	0	2	14	16	19	16	15	18	27	13	24	11	2	0	0	0	0	0	177
0	0	0	0	0	2	4	22	26	21	28	23	29	22	17	4	1	0	0	0	0	0	199
0	0	0	0	0	0	3	24	36	34	42	47	48	34	17	8	0	0	0	0	0	0	293
0	0	0	0	0	0	2	22	74	58	56	66	60	54	15	4	0	0	0	0	0	0	411
0	0	0	0	0	0	0	8	61	70	83	77	72	39	12	0	0	0	0	0	0	0	422
0	0	0	0	0	0	0	2	37	119	126	113	82	54	2	0	0	0	0	0	0	0	535
0	0	0	0	0	0	0	0	20	127	193	158	112	17	0	0	0	0	0	0	0	0	627
0	0	0	0	0	0	0	0	2	90	274	220	71	10	1	0	0	0	0	0	0	0	668
0	0	0	0	0	0	0	0	0	49	309	246	61	4	0	0	0	0	0	0	0	0	669
0	0	0	0	0	0	0	0	1	30	351	332	37	2	0	0	0	0	0	0	0	0	753
0	0	0	0	0	0	0	0	0	34	309	363	18	0	0	0	0	0	0	0	0	0	724
0	0	0	0	0	0	0	0	3	58	291	324	32	0	0	0	0	0	0	0	0	0	708
0	0	0	0	0	0	0	1	7	85	203	246	109	4	0	0	0	0	0	0	0	0	655
0	0	0	0	0	0	0	4	34	93	165	187	115	13	0	0	0	0	0	0	0	0	611
0	0	0	0	0	0	0	7	40	91	118	114	118	36	1	0	0	0	0	0	0	0	525
0	0	0	0	0	0	0	13	49	71	81	89	70	72	9	0	0	0	0	0	0	0	454
0	0	0	0	0	0	1	25	49	59	57	46	57	44	16	0	0	0	0	0	0	0	354
0	0	0	0	0	0	5	24	31	35	34	37	35	34	26	1	0	0	0	0	0	0	262
0	0	0	0	1	2	9	12	21	29	19	27	29	27	28	4	0	0	0	0	0	0	208
0	0	0	0	0	5	18	28	32	25	29	23	23	35	33	19	5	0	0	0	0	0	275
-100.0000																						
0	0	1	1	6	5	13	16	11	12	9	11	17	14	12	12	14	4	1	0	0	0	0
SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN																						
0	0	0	0	1	11	56	208	542	1194	2783	2756	1205	514	201	51	8	0	0	0	0	0	9530

PROTON BEAM RADIUS = .0075 CM
PROTON BEAM SLOPE = .6667 MILLI RADIANS
TARGET LENGTH = 4.0000 CM TUNGSTEN
P BAR KINETIC ENERGY = 4.5000 GEV
P BAR MOMENTUM = 5.3565 GEV/C
P BAR RMS P PERP = .4000 GEV/C
LI LENS GRADIENT = 100.0000 KG/CM
LI LENS LENGTH = 10.0000 CM

Full Mult. Scatt.

Fig 10

CORRELATION PLOT NO 4
HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)
VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.2000

13	34	18	37	78	113	166	169	169	196	194	188	184	168	185	140	99	79	41	26	18

40.0000

0	0	0	0	0	2	12	18	28	36	36	32	22	35	19	5	2	0	0	0	0
0	0	0	0	0	0	4	22	32	34	48	42	30	25	18	2	2	0	0	0	0
0	0	0	0	0	0	3	12	34	50	44	36	35	19	10	5	2	0	0	0	0
0	0	0	0	0	0	1	9	34	55	55	53	45	17	11	7	1	1	0	0	0
0	0	0	0	0	0	0	3	25	54	55	52	31	18	11	1	0	0	0	0	0
0	0	0	0	0	0	0	5	19	60	65	58	33	20	5	0	0	0	0	0	0
0	0	0	0	0	0	0	1	15	42	77	68	36	20	6	4	0	0	0	0	0
0	0	0	0	0	0	0	2	17	55	83	80	42	14	5	1	0	0	0	0	0
0	0	0	0	0	0	0	0	13	47	89	74	40	14	1	0	0	0	0	0	0
0	0	0	0	0	0	1	0	7	40	102	104	43	12	1	1	0	0	0	0	0
0	0	0	0	0	0	0	3	9	34	81	93	37	4	0	0	0	0	0	0	0
0	0	0	0	0	0	0	4	12	49	85	106	57	10	0	0	0	0	0	0	0
0	0	0	0	0	0	0	4	18	44	80	94	54	9	1	0	0	0	0	0	0
0	0	0	0	0	0	1	4	21	49	67	83	57	12	0	0	0	0	0	0	0
0	0	0	0	0	0	2	4	13	53	55	60	46	9	5	0	0	0	0	0	0
0	0	0	0	0	0	4	9	29	35	44	53	47	28	10	0	0	0	0	0	0
0	0	0	1	0	2	0	13	19	31	45	57	47	36	10	2	0	0	0	0	0
0	0	0	0	1	2	11	7	29	39	52	50	37	42	9	4	0	0	0	0	0
0	0	0	0	1	0	3	16	28	32	35	42	32	33	22	5	0	0	0	0	0
0	0	0	0	5	5	22	28	42	47	58	57	66	52	42	13	3	0	0	0	0

-40.0000

13	29	25	47	75	101	124	131	149	144	153	163	129	144	145	146	106	60	65	24	17

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	1	7	11	64	164	444	886	1259	1294	837	429	186	50	10	1	0	0	0

PROTON BEAM RADIUS	=	.0075 CM
PROTON BEAM SLOPE	=	.6667 MILLI RADIANS
TARGET LENGTH	=	4.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3565 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Full Mult. Scatt.

Fig 11

CORRELATION PLOT NO 3
HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)
VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.4000

0	0	0	0	0	0	0	0	1	32	142	108	30	0	0	0	0	0	0	0	0

100.0000

0	0	0	0	0	0	0	0	1	12	53	68	15	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	26	75	83	25	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	32	89	88	33	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	4	25	167	150	30	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	34	193	169	26	3	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	47	205	219	43	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	2	52	268	259	41	3	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	2	67	279	296	54	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	77	315	290	54	5	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	4	56	313	259	61	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	3	66	303	274	69	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	3	70	258	294	78	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	69	309	306	57	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	51	243	239	53	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	3	46	204	219	49	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	2	36	196	174	46	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	29	156	139	33	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	19	121	109	20	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	19	96	83	25	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	2	16	114	94	25	2	0	0	0	0	0	0	0

-100.0000

0	0	0	0	0	0	0	0	0	16	82	72	11	0	0	0	0	0	0	0	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	0	0	0	0	0	32	849	3947	3812	837	29	0	0	0	0	0	0	0

PROTON BEAM RADIUS =	.0300 CM
PROTON BEAM SLOPE =	.1667 MILLI RADIANS
TARGET LENGTH =	0.0000 CM TUNGSTEN
P BAR KINETIC ENERGY =	4.5000 GEV
P BAR MOMENTUM =	5.3565 GEV/C
P BAR RMS P PERP =	.4000 GEV/C
LI LENS GRADIENT =	100.0000 KG/CM
LI LENS LENGTH =	10.0000 CM

<u>No</u> Mult. Scatt.

Fig 12

CORRELATION PLOT NO 4
HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)
VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.2000 .2000

0	0	0	0	0	0	9	48	160	376	548	526	359	166	36	3	1	0	0	0	0	0	0

40.0000

0	0	0	0	0	0	1	5	22	42	52	69	34	20	0	0	0	0	0	0	0	0	245
0	0	0	0	0	0	1	2	16	45	64	65	43	13	2	2	0	0	0	0	0	0	253
0	0	0	0	0	0	0	3	21	45	68	61	41	15	2	1	0	0	0	0	0	0	257
0	0	0	0	0	0	1	3	22	56	51	84	42	11	6	1	0	0	0	0	0	0	277
0	0	0	0	0	0	1	8	17	52	72	73	43	19	7	1	0	0	0	0	0	0	293
0	0	0	0	0	0	0	2	32	44	88	63	41	14	2	1	0	0	0	0	0	0	287
0	0	0	0	0	0	1	11	19	45	75	74	54	16	10	3	0	0	0	0	0	0	308
0	0	0	0	0	0	0	2	20	51	69	58	42	16	10	2	0	0	0	0	0	0	270
0	0	0	0	0	1	2	6	17	55	73	65	37	22	5	0	0	0	0	0	0	0	283
0	0	0	0	0	0	1	4	20	48	80	65	49	12	8	1	0	0	0	0	0	0	289
0	0	0	0	0	0	0	2	14	42	63	81	36	24	10	1	0	0	0	0	0	0	273
0	0	0	0	0	0	2	7	25	63	83	63	31	20	7	0	0	0	0	0	0	0	301
0	0	0	0	0	0	3	11	21	48	67	70	48	16	10	0	0	0	0	0	0	0	294
0	0	0	0	0	0	0	6	19	39	62	73	37	17	10	0	0	0	0	0	0	0	263
0	0	0	0	0	0	1	7	24	38	56	91	38	28	5	0	1	0	0	0	0	0	289
0	0	0	0	0	0	0	5	29	51	76	65	43	23	3	0	0	0	0	0	0	0	295
0	0	0	0	0	0	0	6	19	41	76	87	54	18	7	2	0	0	0	0	0	0	310
0	0	0	0	0	0	0	8	20	39	67	64	54	16	3	0	0	0	0	0	0	0	271
0	0	0	0	0	0	1	4	13	30	66	48	39	13	6	2	0	0	0	0	0	0	222
0	0	0	0	0	0	2	12	22	77	112	112	63	32	8	0	0	0	0	0	0	0	440

-40.0000

0	0	0	0	0	0	6	24	139	366	510	498	318	150	40	7	0	0	0	0	0	0	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	0	0	1	17	114	412	951	1420	1432	869	365	121	17	1	0	0	0	0	0	5720

PROTON BEAM RADIUS = .0300 CM
PROTON BEAM SLOPE = .1667 MILLI RADIANS
TARGET LENGTH = 0.0000 CM TUNGSTEN
P BAR KINETIC ENERGY = 4.5000 GEV
P BAR MOMENTUM = 5.3565 GEV/C
P BAR RMS P PERP = .4000 GEV/C
LI LENS GRADIENT = 100.0000 KG/CM
LI LENS LENGTH = 10.0000 CM

No Mult. Scatt.

Fig 13

CORRELATION PLOT NO 3
HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)
VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.4000 .4000

0	0	0	0	4	16	19	17	26	22	34	31	31	22	21	27	25	4	0	1	0	0	0

100.0000

0	0	0	0	0	0	11	17	20	10	21	18	17	19	23	10	0	0	0	0	0	0	165
0	0	0	0	0	0	5	25	23	30	25	27	24	23	24	5	0	0	0	0	0	0	211
0	0	0	0	0	0	0	25	34	37	45	39	47	35	28	0	0	0	0	0	0	0	291
0	0	0	0	0	0	0	7	70	64	53	66	60	53	16	0	0	0	0	0	0	0	389
0	0	0	0	0	0	0	0	72	90	64	89	72	58	0	0	0	0	0	0	0	0	445
0	0	0	0	0	0	0	0	32	110	129	109	123	35	0	0	0	0	0	0	0	0	539
0	0	0	0	0	0	0	0	0	141	175	161	110	0	0	0	0	0	0	0	0	0	587
0	0	0	0	0	0	0	0	0	69	278	250	61	0	0	0	0	0	0	0	0	0	658
0	0	0	0	0	0	0	0	0	0	346	367	0	0	0	0	0	0	0	0	0	0	713
0	0	0	0	0	0	0	0	0	0	373	397	0	0	0	0	0	0	0	0	0	0	760
0	0	0	0	0	0	0	0	0	0	386	373	0	0	0	0	0	0	0	0	0	0	759
0	0	0	0	0	0	0	0	0	0	372	345	0	0	0	0	0	0	0	0	0	0	717
0	0	0	0	0	0	0	0	0	60	269	242	69	0	0	0	0	0	0	0	0	0	640
0	0	0	0	0	0	0	0	0	118	172	154	134	0	0	0	0	0	0	0	0	0	578
0	0	0	0	0	0	0	0	31	114	117	116	129	28	0	0	0	0	0	0	0	0	535
0	0	0	0	0	0	0	0	68	80	85	97	68	62	0	0	0	0	0	0	0	0	458
0	0	0	0	0	0	0	11	70	58	43	48	47	52	11	0	0	0	0	0	0	0	340
0	0	0	0	0	0	0	32	32	33	40	43	44	37	30	0	0	0	0	0	0	0	291
0	0	0	0	0	0	4	25	28	21	18	22	19	33	29	4	0	0	0	0	0	0	203
0	0	0	0	0	2	25	37	27	27	30	21	24	29	22	27	1	0	0	0	0	0	272

-100.0000

0	0	1	1	4	6	11	10	14	11	6	11	18	12	16	12	9	6	1	0	0	0	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	0	0	2	45	179	507	1062	3042	2974	1048	462	183	46	1	0	0	0	0	0	9551

PROTON BEAM RADIUS	=	0.0000 CM
PROTON BEAM SLOPE	=	0.0000 MILLI RADIANS
TARGET LENGTH	=	4.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3565 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

No Mult. Scatt.

Fig 14

CORRELATION PLOT NO 4

HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.2000 .2000

9	26	20	33	58	115	162	195	168	175	197	192	187	175	199	150	95	71	41	25	17	30	0

40.0000

0	0	0	0	0	0	0	26	40	27	29	33	29	23	17	0	0	0	0	0	0	0	221
0	0	0	0	0	0	0	18	40	40	41	29	41	34	17	0	0	0	0	0	0	0	250
0	0	0	0	0	0	0	2	37	54	39	39	36	40	3	0	0	0	0	0	0	0	250
0	0	0	0	0	0	0	0	36	40	54	58	42	27	0	0	0	0	0	0	0	0	257
0	0	0	0	0	0	0	0	11	55	74	50	54	13	0	0	0	0	0	0	0	0	257
0	0	0	0	0	0	0	0	0	58	79	68	68	0	0	0	0	0	0	0	0	0	273
0	0	0	0	0	0	0	0	0	38	104	105	54	0	0	0	0	0	0	0	0	0	301
0	0	0	0	0	0	0	0	0	5	138	135	13	0	0	0	0	0	0	0	0	0	291
0	0	0	0	0	0	0	0	0	0	151	155	0	0	0	0	0	0	0	0	0	0	306
0	0	0	0	0	0	0	0	0	0	146	156	0	0	0	0	0	0	0	0	0	0	302
0	0	0	0	0	0	0	0	0	0	151	145	0	0	0	0	0	0	0	0	0	0	296
0	0	0	0	0	0	0	0	0	0	161	143	0	0	0	0	0	0	0	0	0	0	304
0	0	0	0	0	0	0	0	0	8	159	152	14	0	0	0	0	0	0	0	0	0	333
0	0	0	0	0	0	0	0	0	39	88	111	36	0	0	0	0	0	0	0	0	0	274
0	0	0	0	0	0	0	0	0	64	88	57	60	0	0	0	0	0	0	0	0	0	269
0	0	0	0	0	0	0	0	7	63	54	48	62	15	0	0	0	0	0	0	0	0	249
0	0	0	0	0	0	0	0	31	57	50	39	53	35	0	0	0	0	0	0	0	0	265
0	0	0	0	0	0	0	2	37	40	39	42	38	37	2	0	0	0	0	0	0	0	235
0	0	0	0	0	0	0	8	32	36	46	23	41	44	20	0	0	0	0	0	0	0	250
0	0	0	0	0	0	2	48	66	59	59	52	59	63	48	3	0	0	0	0	0	0	459

-40.0000

10	15	29	50	65	104	164	141	150	136	141	148	151	133	158	153	95	75	33	26	17	17	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	0	0	0	2	104	337	683	1750	1638	700	328	107	3	0	0	0	0	0	0	5652

PROTON BEAM RADIUS	=	0.0000 CM
PROTON BEAM SLOPE	=	0.0000 MILLI RADIANS
TARGET LENGTH	=	4.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3565 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

No Mult. Scatt.

Fig 15

CORRELATION PLOT NO 3

HORIZ. VARIABLE : DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE: X SLOPE OF RAY (MILLIRADIANS)

-.4000

0	0	0	0	0	0	0	0	0	5	153	147	3	0	0	0	0	0	0	0	0

100.0000

0	0	0	0	0	0	0	0	0	4	65	80	3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	4	99	98	5	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	116	122	2	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	3	194	184	3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	7	211	211	5	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	4	286	222	6	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	12	313	287	9	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	10	343	335	3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	9	370	353	4	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	5	349	323	10	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	7	365	342	12	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	5	350	343	7	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	12	373	338	6	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	6	276	304	12	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	5	245	260	6	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	5	205	237	5	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	5	170	182	4	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	3	136	121	2	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	110	112	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	119	134	3	0	0	0	0	0	0	0	0

-100.0000

0	0	0	0	0	0	0	0	0	2	93	85	1	0	0	0	0	0	0	0	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	0	0	0	0	0	0	108	4697	4598	108	0	0	0	0	0	0	0	0

PROTON BEAM RADIUS	=	0.0000 CM
PROTON BEAM SLOPE	=	0.0000 MILLI RADIANS
TARGET LENGTH	=	0.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3565 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Mult. Scatt., Li Lens only

Fig 16

CORRELATION PLOT NO 4

HORIZ. VARIABLE = DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE= X SLOPE OF RAY (MILLIRADIANS)

-.2000 .2000

0	0	0	0	0	0	0	1	27	274	851	792	272	27	0	0	0	0	0	0	0	0	0

40.0000

0	0	0	0	0	0	0	0	3	24	103	77	23	5	0	0	0	0	0	0	0	0	235
0	0	0	0	0	0	0	0	5	35	82	91	32	3	0	0	0	0	0	0	0	0	248
0	0	0	0	0	0	0	0	7	40	94	94	27	1	0	0	0	0	0	0	0	0	263
0	0	0	0	0	0	0	0	5	27	104	100	35	1	0	0	0	0	0	0	0	0	272
0	0	0	0	0	0	0	0	2	42	105	101	42	2	0	0	0	0	0	0	0	0	294
0	0	0	0	0	0	0	0	1	35	103	118	32	3	0	0	0	0	0	0	0	0	292
0	0	0	0	0	0	0	1	4	38	116	120	36	1	0	0	0	0	0	0	0	0	316
0	0	0	0	0	0	0	0	4	37	106	77	35	2	0	0	0	0	0	0	0	0	261
0	0	0	0	0	0	0	0	1	39	113	99	29	2	0	0	0	0	0	0	0	0	283
0	0	0	0	0	0	0	0	3	32	100	106	34	6	0	0	0	0	0	0	0	0	281
0	0	0	0	0	0	0	0	3	37	119	90	37	2	1	0	0	0	0	0	0	0	289
0	0	0	0	0	0	0	0	2	38	110	92	34	3	0	0	0	0	0	0	0	0	279
0	0	0	0	0	0	0	1	2	47	89	106	50	8	0	0	0	0	0	0	0	0	303
0	0	0	0	0	0	0	0	2	28	103	104	31	4	0	0	0	0	0	0	0	0	272
0	0	0	0	0	0	0	0	2	39	105	105	36	1	0	0	0	0	0	0	0	0	288
0	0	0	0	0	0	0	0	3	49	110	94	34	1	0	0	0	0	0	0	0	0	291
0	0	0	0	0	0	0	0	8	41	117	111	36	1	0	0	0	0	0	0	0	0	314
0	0	0	0	0	0	0	0	1	24	87	102	30	9	1	0	0	0	0	0	0	0	254
0	0	0	0	0	0	0	0	3	27	84	93	23	5	0	0	0	0	0	0	0	0	235
0	0	0	0	0	0	0	0	5	53	146	174	60	2	0	0	0	0	0	0	0	0	440

-40.0000

0	0	0	0	0	0	0	0	19	217	773	751	265	20	1	0	0	0	0	0	0	0	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	0	0	0	0	2	66	732	2096	2054	696	62	2	0	0	0	0	0	0	0	5710

PROTON BEAM RADIUS	=	0.0000 CM
PROTON BEAM SLOPE	=	0.0000 MILLI RADIANS
TARGET LENGTH	=	0.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.5000 GEV
P BAR MOMENTUM	=	5.3565 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Mult. Scatt., Li Lens only

Fig 17

CORRELATION PLOT NO 3

HORIZ. VARIABLE = DISTANCE FROM AXIS X (CM)

VERTICLE VARIABLE= X SLOPE OF RAY (MILLIRADIANS)

-.4000																					
	0	0	1	2	3	12	28	26	29	32	35	21	34	23	17	24	16	18	4	0	0
100.0000																					
	0	0	0	0	0	3	10	20	28	18	14	16	19	14	13	5	5	0	0	0	0
	0	0	0	0	0	6	16	16	15	24	35	30	20	19	27	6	2	0	0	0	0
	0	0	0	0	0	0	10	33	39	42	33	40	37	30	25	6	3	0	0	0	0
	0	0	0	0	0	0	7	22	51	52	62	70	49	45	21	3	1	0	0	0	0
	0	0	0	0	0	0	3	22	61	59	91	74	59	48	19	2	0	0	0	0	0
	0	0	0	0	0	0	1	10	62	86	117	112	103	40	13	4	0	0	0	0	0
	0	0	0	0	0	0	0	5	54	112	167	148	89	37	7	2	0	0	0	0	0
	0	0	0	0	0	0	0	1	21	116	223	209	83	35	3	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	12	90	233	234	100	20	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	12	97	264	265	88	9	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	11	89	253	266	88	14	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	2	6	101	242	267	96	16	1	0	0	0	0	0	0
	0	0	0	0	0	0	0	5	22	94	181	198	118	23	3	0	0	0	0	0	0
	0	0	0	0	0	0	0	7	32	96	127	154	108	33	1	0	0	0	0	0	0
	0	0	0	0	0	0	3	10	34	93	84	123	84	47	9	0	0	0	0	0	0
	0	0	0	0	0	0	3	12	52	74	85	79	64	46	17	4	0	0	0	0	0
	0	0	0	0	1	1	5	27	54	53	47	53	50	48	20	5	0	0	0	0	0
	0	0	0	0	0	0	5	22	31	39	40	37	36	35	31	10	0	0	0	0	0
	0	0	0	0	0	1	10	14	21	15	31	25	23	23	22	7	4	1	0	0	0
	0	0	0	0	2	6	22	21	21	31	28	34	26	27	22	24	6	1	0	0	0
-100.0000																					
	0	0	0	5	3	14	10	21	12	13	17	17	19	15	13	16	12	4	4	0	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	0	0	3	17	95	249	639	1381	2357	2434	1340	609	254	78	21	2	0	0	0

PROTON BEAM RADIUS	=	.0300 CM
PROTON BEAM SLOPE	=	.1667 MILLI RADIANS
TARGET LENGTH	=	4.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.4696 GEV
P BAR MOMENTUM	=	5.3256 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Full Mult. Scatt.

Fig 18

CORRELATION PLOT NO 4

HORIZ. VARIABLE = DISTANCE FROM AXIS X (CM)
VERTICLE VARIABLE= X SLOPE OF RAY (MILLIRADIANS)

-.2000 .2000

10	51	41	66	83	133	152	159	154	206	181	201	162	180	141	133	86	79	56	36	14	50	0
40.0000																						
0	0	0	0	3	14	16	16	22	26	32	28	32	18	12	9	8	1	0	1	0	0	238
0	0	0	1	1	6	13	14	33	32	39	32	25	23	16	12	4	2	1	1	0	0	255
0	0	0	0	0	3	6	20	28	53	43	38	28	20	15	12	3	2	1	0	0	0	272
0	0	0	0	1	3	6	21	22	41	43	47	31	18	7	10	5	1	0	0	0	0	256
0	0	0	0	0	1	7	17	35	38	43	59	37	26	17	8	1	2	0	0	0	0	291
0	0	0	0	0	2	3	11	25	38	50	46	40	22	19	10	1	0	0	0	0	0	267
0	0	0	0	0	2	5	15	16	44	59	54	47	21	14	5	1	0	0	0	0	0	283
0	0	0	0	0	0	2	14	26	47	42	65	34	38	8	3	4	0	0	0	0	0	283
0	0	0	0	0	0	5	8	32	38	68	66	39	23	14	4	0	0	0	0	0	0	297
0	0	0	0	0	0	5	7	33	44	67	65	43	22	7	1	0	0	0	0	0	0	294
0	0	0	0	0	0	3	12	16	55	58	64	45	23	9	5	0	0	0	0	0	0	290
0	0	0	0	0	1	5	14	29	37	62	62	46	34	5	3	2	0	0	0	0	0	300
0	0	0	1	0	0	4	11	29	43	47	63	41	27	9	6	0	0	0	0	0	0	281
0	0	0	1	0	0	1	13	23	41	53	61	48	27	8	4	1	0	0	0	0	0	281
0	0	0	0	0	0	3	17	26	42	57	63	40	30	12	6	3	1	0	0	0	0	300
0	0	0	0	0	1	7	13	27	43	52	46	36	22	13	8	2	1	0	0	0	0	271
0	0	0	0	3	4	9	19	17	25	25	36	39	38	20	7	3	1	0	0	0	0	246
0	0	0	1	3	0	4	18	22	30	29	50	37	28	17	3	6	1	0	0	0	0	249
0	0	0	0	1	4	10	17	19	24	29	28	35	21	23	5	5	0	1	0	0	0	222
0	0	1	1	6	8	21	30	47	41	42	48	54	55	27	19	13	2	2	0	0	0	417
-40.0000																						
23	33	34	50	74	108	103	117	162	159	141	168	143	129	135	127	99	64	66	41	25	32	0

SUMMED DISTRIBUTIONS AT BOTTOM AND RIGHTMOST COLUMN

0	0	1	5	18	49	135	307	527	782	940	1021	777	536	272	140	62	14	5	2	0	0	5593

PROTON BEAM RADIUS	=	.0300 CM
PROTON BEAM SLOPE	=	.1667 MILLI RADIANS
TARGET LENGTH	=	4.0000 CM TUNGSTEN
P BAR KINETIC ENERGY	=	4.4696 GEV
P BAR MOMENTUM	=	5.3256 GEV/C
P BAR RMS P PERP	=	.4000 GEV/C
LI LENS GRADIENT	=	100.0000 KG/CM
LI LENS LENGTH	=	10.0000 CM

Full Mult. Scatt.

Fig 19

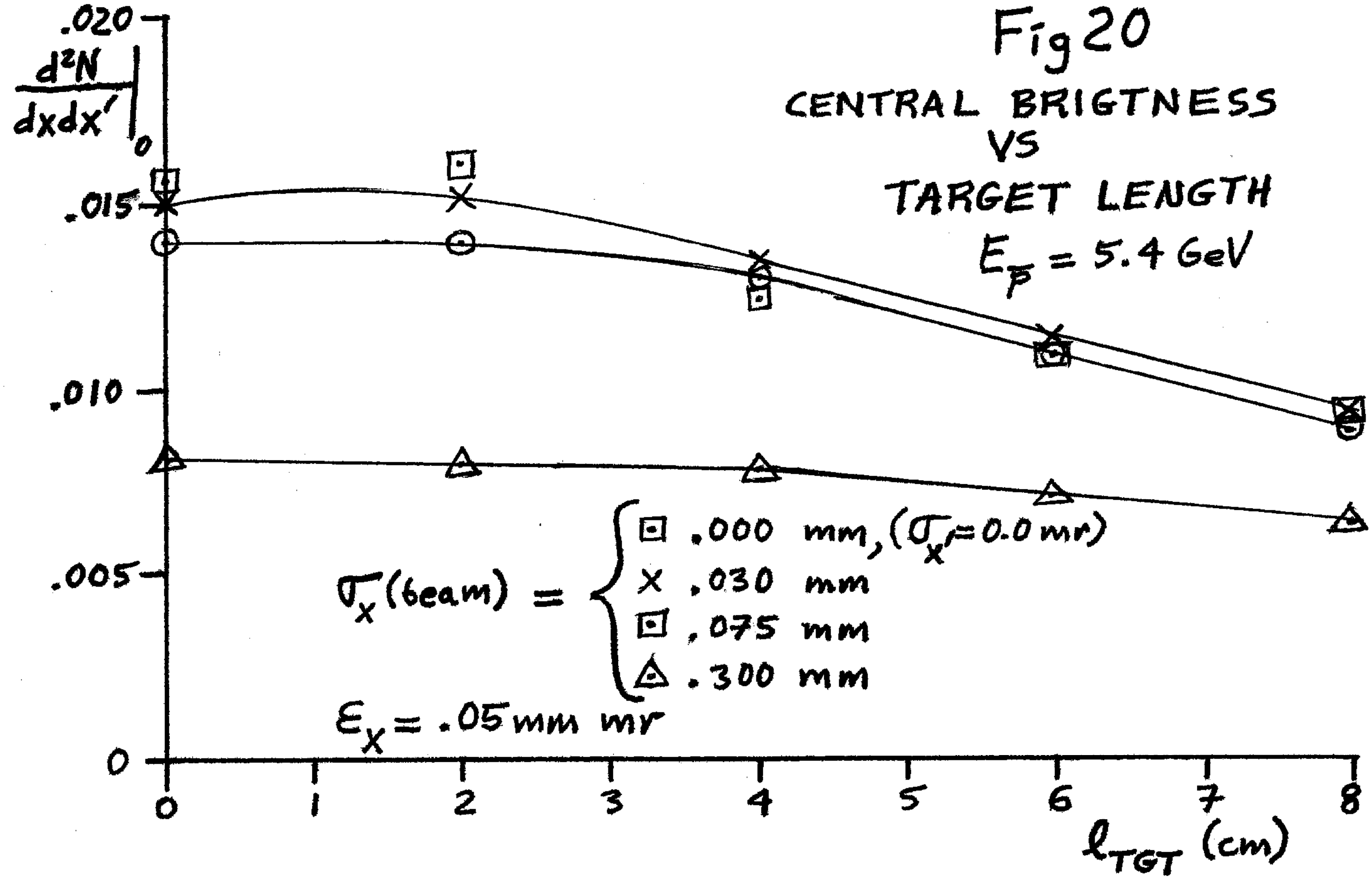


Fig 20
CENTRAL BRIGTNESS
VS
TARGET LENGTH
$E_p = 5.4$ GeV
$\frac{d^2N}{dxdx'}\Big|_0$
.020
.015
.010
.005
0
σ_x(beam) =
.000 mm, ($\sigma_{x'}$=0.0 mr)
.030 mm
.075 mm
.300 mm
ε_x = .05 mm mr
0 1 2 3 4 5 6 7 8
ℓ_{TGT} (cm)

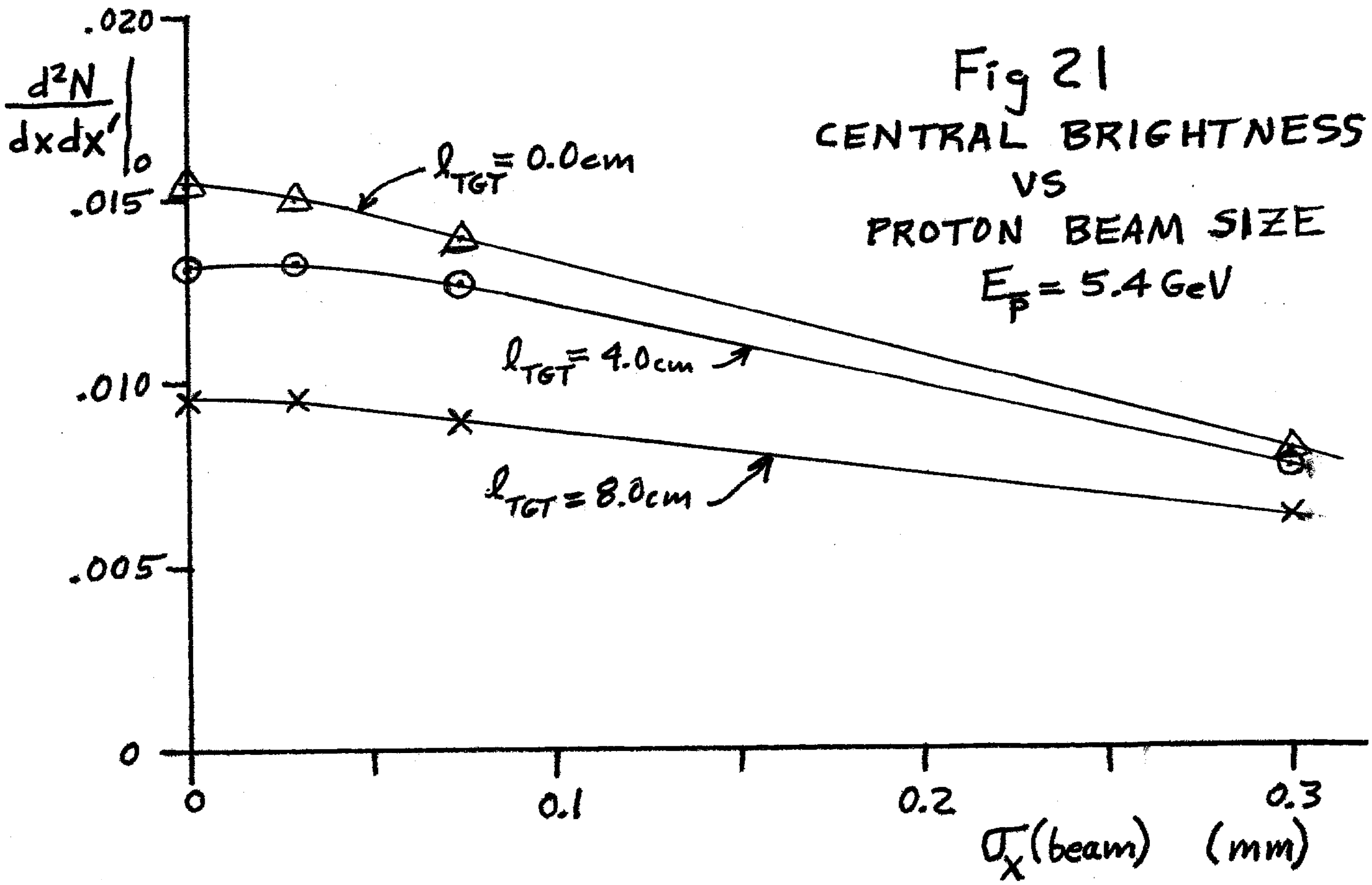
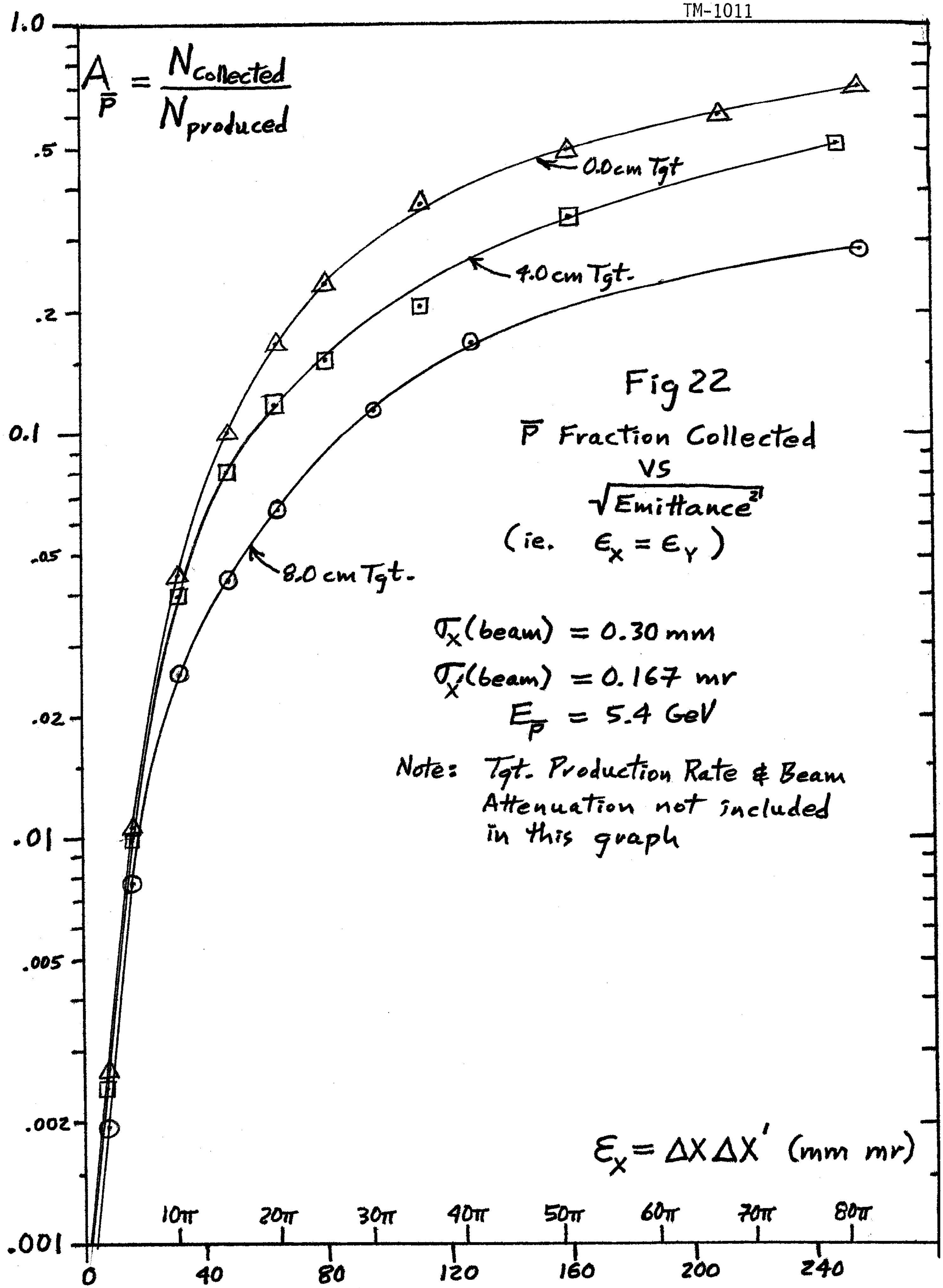


Fig 21
CENTRAL BRIGHTNESS
VS
PROTON BEAM SIZE
E_p= 5.4 GeV
$\frac{d^2N}{dxdx'}\Big|_0$
.020
.015
.010
.005
0
ℓ_{TGT}= 0.0cm
ℓ_{TGT}= 4.0cm
ℓ_{TGT} = 8.0cm
0 0.1 0.2 0.3
σ_x(beam) (mm)


$A_{\bar{p}} = \frac{N_{collected}}{N_{produced}}$
1.0
.5
.2
0.1
.05
.02
.01
.005
.002
.001
0.0 cm Tgt
4.0 cm Tgt.
8.0 cm Tgt.
Fig 22
$\bar{P}$ Fraction Collected
VS
$\sqrt{\text{Emittance}^2}$
(ie. $\epsilon_x = \epsilon_y$)
σ_x(beam) = 0.30 mm
$\sigma_{x'}$(beam) = 0.167 mr
$E_{\bar{p}}$ = 5.4 GeV
Note: Tgt. Production Rate & Beam Attenuation not included in this graph
$\epsilon_x = \Delta X \Delta X'$ (mm mr)
10π
20π
30π
40π
50π
60π
70π
80π
0
40
80
120
160
200
240

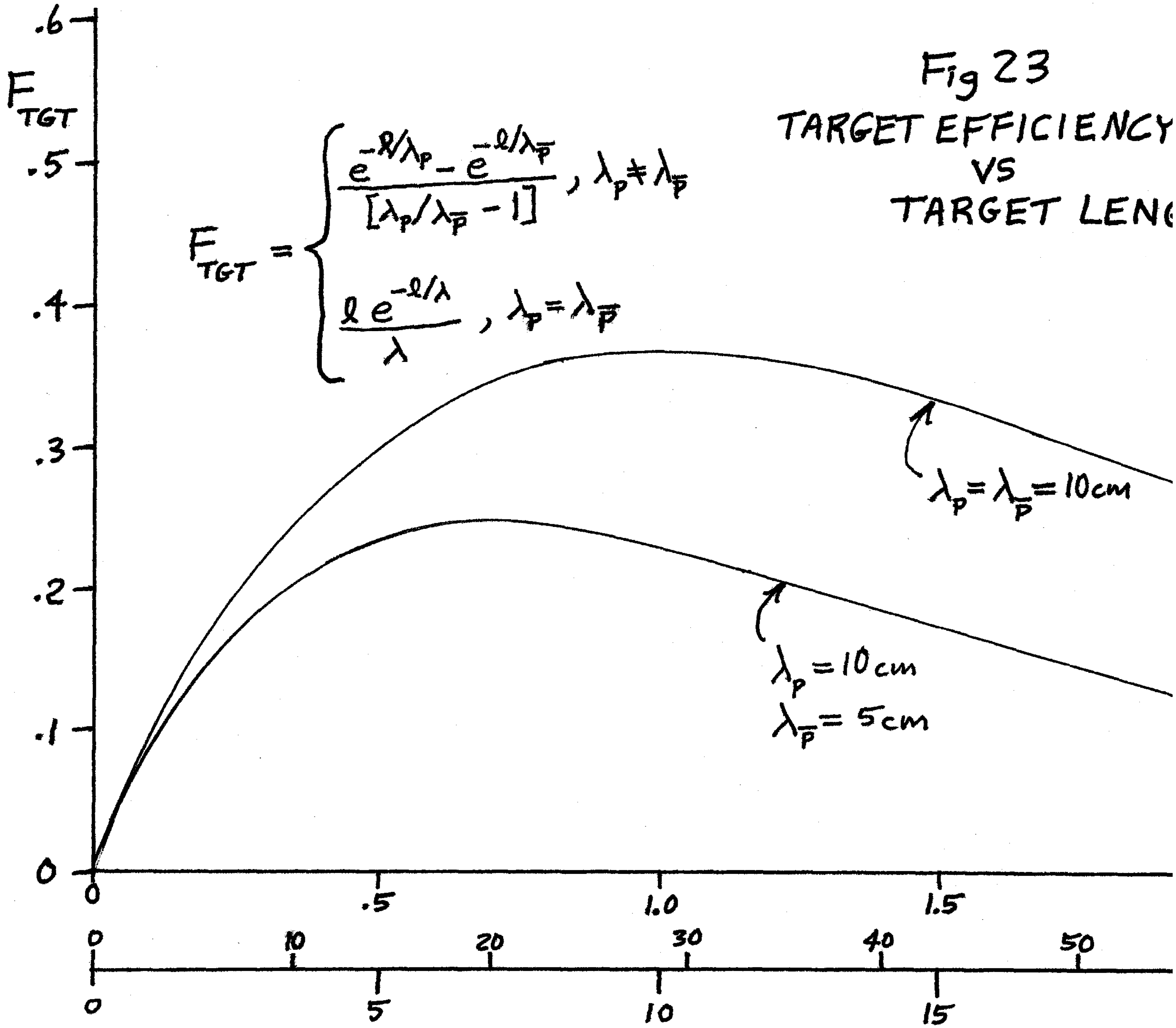
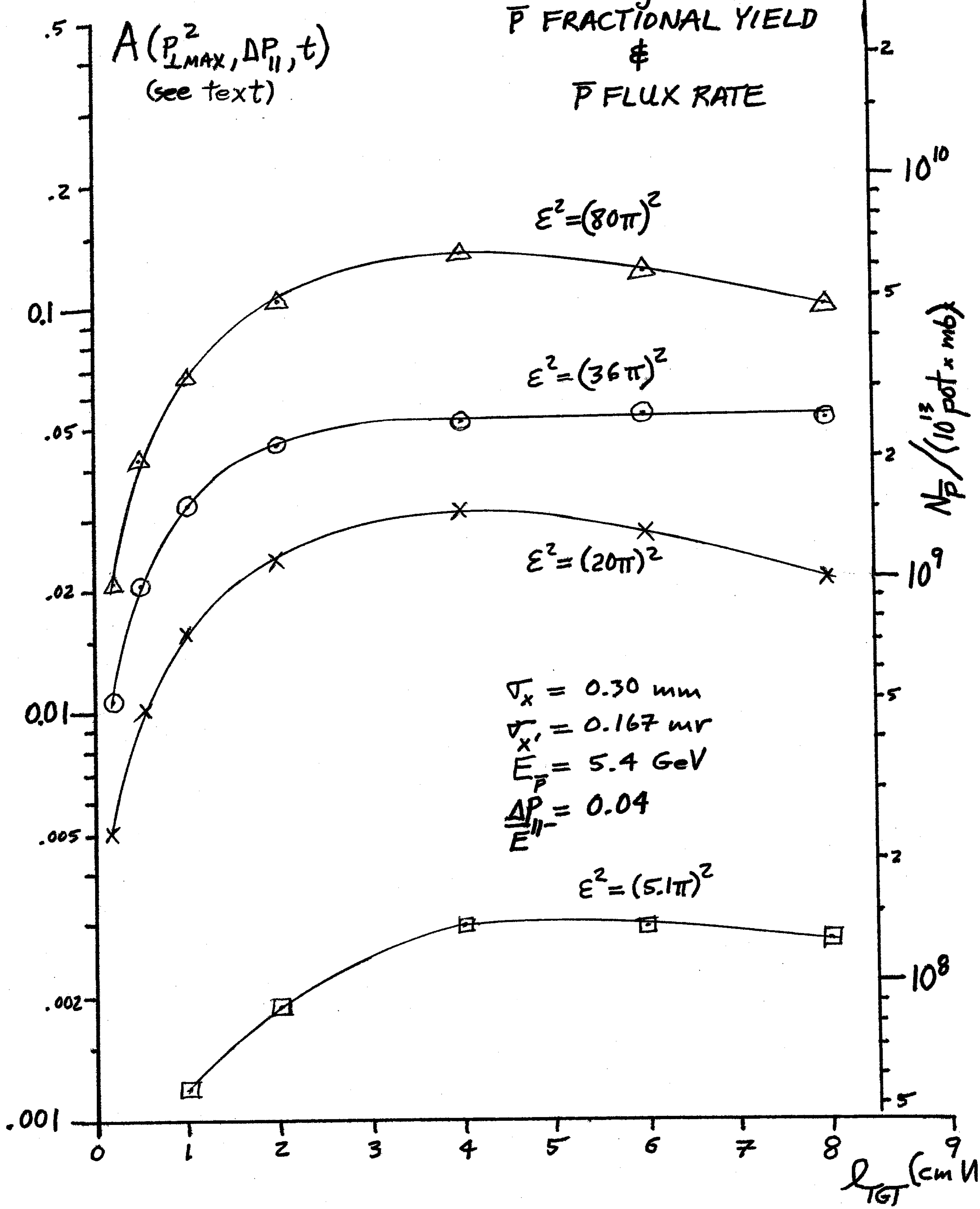


Fig 23
TARGET EFFICIENCY
VS
TARGET LENG
F_{TGT}
$F_{TGT} = \begin{cases} \dfrac{e^{-\ell/\lambda_p} - e^{-\ell/\lambda_{\bar{p}}}}{[\lambda_p/\lambda_{\bar{p}} - 1]}, & \lambda_p \neq \lambda_{\bar{p}} \\ \dfrac{\ell e^{-\ell/\lambda}}{\lambda}, & \lambda_p = \lambda_{\bar{p}} \end{cases}$
$\lambda_p = \lambda_{\bar{p}} = 10cm$
$\lambda_p = 10cm$
$\lambda_{\bar{p}} = 5cm$
.6
.5
.4
.3
.2
.1
0
0
.5
1.0
1.5
0
10
20
30
40
50
0
5
10
15

Fig 24


P̄ FRACTIONAL YIELD
&
P̄ FLUX RATE
A(P²⊥MAX, ΔP∥, t)
(see text)
ε² = (80π)²
ε² = (36π)²
ε² = (20π)²
ε² = (5.1π)²
σx = 0.30 mm
σx' = 0.167 mr
Ep̄ = 5.4 GeV
ΔP∥/E = 0.04
Np̄/(10¹³ pot × mb)
ℓTGT (cm)
.5
.2
0.1
.05
.02
0.01
.005
.002
.001
0
1
2
3
4
5
6
7
8
9
2
10¹⁰
5
2
10⁹
5
2
10⁸
5